Subband Coding Methods for Seismic Data Compression[1]

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A typical seismic analysis scenario involves collection of data by an array of seismometers, transmission over a channel offering limited data rate, and storage of data for analysis. Seismic data analysis is performed for monitoring earthquakes and for planetary exploration as in the planned study of seismic events on Mars. Seismic data compression systems arc required to cope with the transmission of vast amounts of data over constrained channels and must be able to accurately reproduce occasional high energy seismic events.

Wc propose a compression algorithm that includes three stages: a decor-relation stage based on subband coding, a quantization stage that introduces a controlled amount of distortion to allow for high compression ratios, and a lossless entropy coding stage based on a simple but efficient block-adaptive arithmetic coding method. Adaptivity to the non-stationary behavior of the waveform is achieved by partitioning the data into blocks which arc encoded separately. The compression ratio of the proposed scheme can be set to meet prescribed fidelity requirements, i.e. the waveform can be reproduced with sufficient fidelity for accurate interpretation and analysis. The distortions incurred by this compression scheme arc currently being evaluated by several seismologists.

Subband coding methods are particularly suited to the decorrelation of highly non-stationary processes such as seismic events, and can provide controlled resolution independently in the time and frequency domains. For seismic data, most of the energy is concentrated in the low-frequency subbands, which suggests the usc of the logarithmic or dyadic decomposition. The decorrelation stage is implemented by quadrature mirror filters using a lattice structure. This technique requires periodic extension of the data, which often produces high frequency components at'the edges of data blocks. These effects arc magnified for longer filters. Longer filters arc also more likely to introduce noticeable. spurious effects at the onset of a high energy seismic event.

Each subband is quantized using a uniform quantizer and mapped to a fixed length binary codeword, The first few coefficients from all but the lowest subband arc separately compressed using runlength encoding of the leading zeros in the binary codewords for these coefficients. The remaining coefficients arc compressed using a low-overhead block-adaptive binary arithmetic coding separately on each bit layer. The compressed bits arc sent in order of significance so that the system behaves in a progressive transmission fashion and successive refinements of the data can be requested by the user. This allows seismologists to first examine a coarse version of a waveform with minimal use of the channel before deciding where higher resolution is required. Encoding is done with high efficiency due to the low overhead required to specify the parameters of the arithmetic encoder,

Rate-distortion performance results on seismic waveforms are presented for various filter banks and numbers of levels of decomposition.

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[1] The research described in this abstract was carried out at the Jet Propulsion laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration.